FINAL REPORT
(September 15, 2002 – September 14, 2003)

Instrumentation Offered by the Letter From

Department of the Army
U.S. Army Research Laboratory
P.O. Box 12211, Research Triangle Park, NC 27709-2211

Confirming Through

Department of the Air Force
Air Force Office of Scientific Research (AFOSR)
4015 Wilson Boulevard, Arlington, Virginia 22203 - 1954

<koto.white@afosr.af.mil>
<pkcontracting@afosr.af.mil>

Reference: Control No, ISP02-165
(News Release No. 337-0 dated June 28, 2002)
Award # F49620-02-1-0441

Processing and Testing Instrumentation for the Microelectronics Laboratory

Submitted to

Air Force Office of Scientific Research (AFOSR)

Submitted by

Department of Electrical Engineering
School of Engineering and Technology
Alabama Agricultural and Mechanical University
P.O. Box 297, Normal, Alabama 35762

June 30, 2005

FINAL REPORT
(September 15, 2002 – September 14, 2003)

Reference: Control No, ISP02-165
(News Release No. 337-0 dated June 28, 2002)
Award # F49620-02-1-0441

Processing and Testing Instrumentation for the Microelectronics Laboratory

Submitted to

Air Force Office of Scientific Research (AFOSR)
4015 Wilson Boulevard, Room 713, Arlington, Virginia 22203 - 1954

Principal Investigator:

M. A. Alim, Ph.D., *Principal Investigator*
Associate Professor
Department of Electrical Engineering
Alabama A & M University
P.O. Box 297
Normal, Alabama 35762
Telephone: (256) – 372 - 5562
Fax: (256) – 372 - 5855
Email: <*mohammad.alim@email.aamu.edu*>

Personnel Listed in this Project: **K. B. Cook**, Ph.D., *Co-Investigator*

Authorized Official of the University: **Rose M. Yates**, Ph. D.
Interim Vice President, Research and Development

June 30, 2005

Table of Contents

LIST OF FIGURES

PREVIEW OF THIS REPORT

A Report on the materialized proposal entitled "**Processing and Testing Instrumentation for the Microelectronics Laboratory**" was sent by using regular postal mail service during the Spring 2004 semester having a date of December 2003. Recently I was drawn attention that a Report is necessary to send for the same proposal. This situation prompts that the Report is either lost or did not reach to the destination through the regular mailing system. Invariably it was not sent electronically. Now it is found that the copy of that Report is also missing from the computer storage at Alabama A & M University (AAMU) and cannot be reproduced as it was submitted then. The reason for missing Report in the computer storage is associated with few times virus infection in the hard drive, and eventually the same computer was updated with a new one. Thus, several things including documents have been permanently lost as they could not be recovered.

Considering demand and requirement for the report it is decided that a fresh report is prepared from the scratch, and then send via insured/registered mail assuring of receiving the report for the file. Thus, the present report is prepared using most recent features of the nascent **Microelectronics Laboratory** in the new Engineering and Technology Building (ETB) established in the Department of Electrical Engineering at Alabama A & M University. Altogether this report updates the present status of the Microelectronics Laboratory although the funding has come from concurrent multiple sources.

THE REAL CIRCUMSTANCE AND THE LATE REPORT

The **Report** sent in Spring 2004 was little late. The real situation with the newly established Department of Electrical Engineering at Alabama A & M University (**AAMU**) involves several unavoidable concurrent issues. One of them was to achieve ABET accreditation and moving to the newly constructed building. In future, late submission of the Report will not be a practice as the Department reaches to a mature operation. The Department received **ABET EAC EC-2000** accreditation in August 2001 making effective in May 1999 and renewed in Fall 2003 following visits in Fall 2000 and Fall 2002, respectively. Achieving such a high priority goal in conjunction with the renewal of **SACS** (Southern Accreditation of Colleges and Schools) at AAMU was a massive thrust at the same time.

The Department of Electrical Engineering began offering courses in the ***Microelectronics*** option in Fall 1999 where the **PI** (Dr. M. A. Alim) was the front leader for this option. Since then the **PI** has been extremely busy with multi-task challenges and undertaking overloads from the University to accomplish the goals and objectives of the newly established programs within the Department. The State of Alabama has provided funds to complete the new 86,000 sq. ft. building of the **School of Engineering and Technology** which is operating since Spring 2003. The new laboratories are continuously being installed since then, and they are still in the process of re-arrangement and installation as the Department moved to this new building from a previously squeezed initial spacing at *Carver Complex North* building. These installation processes are very time consuming during the academic year but has become accessible to the students and the faculty members.

THE NEW ELECTRICAL ENGINEERING PROGRAM

The Alabama A & M University is a *land grant* **HBCU** Institution, established in 1890's to serve the needs of the minority population of the State of Alabama. During the 1970's, the University entered into a lawsuit to acquire necessary funds to carry out its land-grant mission. In 1995, the court order authorized the University to establish *two new engineering programs*, one in **Electrical Engineering** and another in **Mechanical Engineering**. The *Department of Electrical Engineering* offers BS degree in electrical engineering. In addition to the usual *general electrical engineering* option, the program offers options in (1) *Microelectronics* and (2) *Computer Engineering.*

The newly established Department of Electrical Engineering was housed at Carver Complex North in Fall 1996 and began the program by recruiting students. The regular Undergraduate laboratories began operating by acquiring step-wise progressing instruments. The courses in the ***Microelectronics*** option were first offered in Fall 1999 through the initiative of the **PI**. Each of the courses in this option was structured and offered initially by the **PI**. Upon joining the Department in January 2000 Dr. K. B. Cook gradually began to participate in structuring this option with the **PI**.

The new **Engineering and Technology Building** (ETB) was completed in December 2002 and regular classes started in Spring 2003. Transferring Undergraduate laboratory instruments and then re-installation became a time consuming task. As of today two *Microelectronics* courses are structured with the requirements of the ***Practicum Courses*** **(Laboratory Practices)** involving facilities in two laboratories. The recent addition of a new faculty, Dr. Zhigang Xiao, in January 2005 has provided assistance in the laboratory operations.

RECOGNITION OF THE PRINCIPAL INVESTIGATOR (Dr. M. A. Alim)

Having a tight schedule including over loaded responsibilities the Principal Investigator (PI), Dr. M. A. Alim, has received the highest scholarly honor of the Alabama A & M University – "**Researcher of the Year 2003**" on August 14, 2003. Dr. Alim is looking forward to continue to preserve this honorable dignity in the coming future through his contributions in the development of the FACT and FDC laboratory facilities at AAMU.

EXECUTIVE SUMMARY

The **Microelectronics Laboratory** in the Department of Electrical Engineering at Alabama A & M University (AAMU) has acquired basic infrastructure instruments for both processing and characterization purposes. These instruments accommodate necessary vital components of running an initial stage laboratory experiments for the Undergraduate courses for the students in the ***Microelectronics*** option. Though this laboratory is not complete but serves the initial purpose at this moment for these Undergraduate students. Some characterization instruments may be used for testing and evaluation as well. Several sources of funds including this **AFOSR** fund are used in erecting this laboratory at the functional level. Further funding sources are continuously sought from several corners to run this laboratory on a daily basis. The list of the instruments along with the installed photographs is provided in this Report.

The **Microelectronics Laboratory** at AAMU has two aspects of operation serving two basic Undergraduate courses [**EE452**: *Semiconductor Instrumentation*, and **EE451**: *Integrated Circuit Fabrication*] in the ***Microelectronics*** option program within the Department of Electrical Engineering curricula. Thus, two brochures have been prepared to focus capabilities of the Department of Electrical Engineering. These are:

(1) Failure Analysis, Characterization, and Testing (**FACT**) Laboratory serving the course **EE452**; and

(2) Fabrication Development Center (**FDC**) serving the course **EE451**.

Each course is designed with three credit hours having one hour equivalent to the associated laboratory curricula.

This laboratory is near operation with the sessions/classes for these two courses since Fall 2004. During Fall 2003 the laboratory was used for teaching EE451 while the laboratory for EE452 was in the installation process. EE451 is based on fabrication only. During Spring 2004 EE452 was taught with the basics of characterization and testing involving forward and reverse engineering technologies for variety integrated circuits including equivalent circuit modeling of the semiconductor devices. Concurrently instrumentation became a pivoting subject of this course.

The School of Engineering and Technology is housed in a new building known as Engineering and Technology Building (ETB) comprising of about 86,000 sq. ft. It was completed during December 2002, and began operating with the classes in Spring 2003. The size of the designed class 1,000 clean room is about 2,500 sq. ft. This clean room is in operation and Dr. K. B. Cook serves as the contact person for the **Fabrication Development Center**. He is assisted by a newly hired faculty, Dr. Zhigang Xiao, for laboratory operations. This new hire in January 2005 is related to the expanded laboratory facilities for the aforementioned two courses and enhanced class schedules with growing enrollment each year.

INTRODUCTION

Upon materializing funding (**AFOSR**) of **$180,000** to develop the infrastructure of the **Microelectronics Laboratory** at AAMU the Department emphasized instrument listing. Concurrent funds were also accumulated to achieve the ultimate goals for operating this laboratory. The anticipated class 1,000 clean room of 2,500 sq. ft. was designed with floor arrangement for the instruments In order to achieve maximum benefit with increasing costs excellent conditioned instruments were in the priority listing. Thus, used instruments were procured wherever possible. Also several new instruments were purchased. Since there was an access to other funds in a concurrent manner, the instruments were prioritized with respect to the sequence of pricing of both used and new instruments.

Based on the type of incoming instruments two laboratory spaces were used for installation and operation as the area in the clean room was not adequate. The **Fabrication Development Center** (FDC) primarily housed all instruments related to fabrication and processing. The **Failure Analysis, Characterization, and Testing** (FACT) **Laboratory** incorporated all characterization and testing instruments. These instruments are also used for evaluation of microelectronic and hybrid devices including integrated circuits.

FEATURES OF THE LABORATORY FACILITIES

Two brochures are prepared by the Department of Electrical Engineering at AAMU displaying capabilities of the **Microelectronics Laboratory** facilities. These two brochures reflect **FACT** and **FDC** instrumental operations. The summary of these instrumental operations incorporated in each brochure is shown in **Figure 1 and Figure 2**. The content of each brochure is reproduced below as it is not very legible.

1. Failure Analysis, Characterization, and Testing (FACT) Laboratory

The Failure Analysis, Characterization, and Testing Facilities have the capabilities to support evaluation of the Microelectronic Systems based on both Single Crystals and Polycrystals technologies using state-of-the-art instrumentation. The Microelectronic Systems include both Unipolar and Bipolar Junction Devices and often noted as Hybrid Device Systems for the Polycrystalline Semiconductors. This facility supports the Microelectronic option program offered by the Department of Electrical Engineering. This program option offers four specialty courses dedicated to the area of Microelectronics having about a dozen of students per year. Students finishing this program are exposed to the projects involving device electronics and integrated circuits including modeling of conduction processes and equivalent circuit modeling. Also they are exposed to the studies on degradation and bias stability of the Hybrid Systems.

Work in this facility is under the direction of Dr. M. A. Alim, Associate Professor in the Department of Electrical Engineering. He has initiated developing this facility in conjunction with the development of the Fabrication Development Center within the Department of Electrical Engineering. He has directed and guided numerous product-related projects in a diversified arena extensively involving a variety of Hybrid Microelectronic Devices and

Systems using large and small band gap electronic materials in Private Industries, Government Organizations, and Academic Institutions in Alabama, Tennessee, Ohio, and Wisconsin. Dr. Alim has taught and developed each of the Microelectronic option courses and collaborated with the University of Massachusetts at Lowell to develop an active Microelectronics option program at Alabama A & M University. His involvement includes research activities on electrical components such as resistors, capacitors, inductors, transformers, resonators, varistors, thermisters, sensors, etc.

Instrumentation and Tools

The Immittance Spectroscopy (Impedance or Admittance) is a powerful non-destructive tool in delineating underlying competing operative phenomena in variety materials and devices. Thus, it provides characterization as well as evaluation and quality control of the end products via smart technique. For characterization and evaluation purposes ultimately an equivalent circuit model can be developed comprising of lumped elements portraying each competing mechanism and operative phenomenon within the material system. Thus, multi-junction systems are delineated into a simple form that prompts processing or fabrication changes. Single-junction through multi-junction and hybrid systems can be characterized efficiently using this facility. The characterization, evaluation, and testing of material systems and variety devices are *non-destructive*. The Department of Electrical Engineering is equipped with *two impedance analyzers* (HP4192A and Solartron 1260) ranging measurement frequencies from 1 *mHz* through *13 MHz*. Semiconductors are analyzed via four-point probing as well as Hall Effect – van der Pauw techniques. Single Junction devices can be analyzed using HP4145 Semiconductor Parametric Analyzer. Junction features of variety semiconductor devices can be evaluated at the Scanning Electron Microscopy Facility. The SEM allows probing both Single Crystal and Polycrystal devices depicting involved conduction areas. The elemental analyses of selected areas of the devices or junctions are also possible using EDS (Energy Dispersive Spectroscopy) technique.

Anticipated Uses

Although the **Failure Analysis, Characterization, and Testing (FACT) Facilities** is developed for Microelectronics students to support the curricula and conducting research in the Department of Electrical Engineering but it is accessible and available to support other organizations according to their requirements. This facility is also available to conduct basic and applied research to achieve an eventual product. It is a perfect facility to initiate SBIR (Small Business Innovation Research) in addition to large organizations' basic needs. All tools/techniques noted herein are available for innovating solid-state (semiconductor) based devices for variety sensors, transducers, thermisters, thyristers, electrical components (resistors, capacitors, inductors, transformers, etc.), varistors, large and low energy handling devices, etc.

Other tools and techniques are readily available for use. Among those are highlighted as various Crystal Growth Techniques, Bulk Nano-Powders, X-Ray Diffraction (XRD), Elemental Analysis via ICP-AES, etc. Degradation studies of materials and devices can be conducted using all the tools and techniques noted above, and then solutions may be provided to the problems of the end products.

The FACT center will also support research in material characterization, device design and development, performance demonstration under non-nominal conditions and device manufacture. The center will be an industry-recognized resource for component and device testing. The center will bring together the technical talent of subject matter experts in academia, Government and industry with the resources of the FACT laboratory to do microelectronics component and device testing. The laboratory will be equipped to do Burn-in and Qualification testing, Stress, accelerated Stress and Accelerated Lifetime Testing, small batch Environmental Stress Testing and Failure Analysis of microelectronics components and devices. The FACT laboratory will be used to train students in the processes and techniques of microelectronic device testing and analysis. Students will be exposed to the performance realities of "real" devices under stress, and will be trained to analyze the cause of failures in the devices they design. Students will be instructed in the requirements, procedures and techniques of qualification, stress and accelerated life-time testing. They will leave the program with an understanding of the design and build process and will have developed the familiarity with real devices that can only be gained from performance testing and analysis of failures.

Summary Content in the Outer Cover Page

This facility provides the personnel and resources to support research activities in the Microelectronics option emphasizing Bulk Nano-Electronics while serving conventional and innovative smart novel Hybrid Devices.

The aforementioned text is provided in the **FACT Laboratory** brochure as shown in **Figure 1**.

2. Fabrication Development Center (FDC)

The Fabrication Development Center includes a team of instructors and advanced students providing the capability to develop prototypes, support research and education in microelectronics. The development team makes use of a 2500 square foot clean room to fabricate solid state devices or complete IC chips. The facility also supports the Department of Electrical Engineering's microelectronics concentration. This program option offers specialty courses dedicated to the area of solid state electronics. Students in the program have designed projects such as digital memory systems and linear operational amplifiers.

Work in the facility is carried out under the direction of Dr. Koy B. Cook and Dr. Zhigang Xiao, professors of electrical engineering. Dr. Cook has 30 years of combined experience directing projects in industry and teaching engineering at Universities in Alabama and Florida. Here at Alabama A&M, Dr. Cook's students use Multisim and Tanner TCAD tools to design and simulate IC chips. Most recently, students are using Silvaco Supreme Process Simulation tools to develop advanced processes for silicon structures. Dr. Xiao has taught electrical engineering for over ten years. Both Professors have experience in process engineering including plasma-enhanced chemical vapor deposition, low pressure chemical vapor deposition, thin films, photolithography, diffusion, and ion implantation. Dr. Xiao's most recent work has been in nanotechnology and Dr. Cook's in sensors. Dr. Cook is a senior member of the IEEE and a registered professional engineer. Both have extensive publications.

Equipment

The Fabrication Development Center contains the basic process and fabrication tools necessary to develop new technology or instruct in microelectronics. Fabrication equipment includes a state-of-the-art custom computer controlled six-tube Steed diffusion furnace system with expansion capability for LPCVD polysilicon and silicon nitride, custom CHA dual e-beam evaporator, Karl Zuss MA 56 mask aligner, Tempress dicing saw, Westbond die bonder, Rudolph ellipsometer, Technics planer plasma etch system, Technics etcher/stripper, numerous class 100 laminar flow dry and wet work stations, Signitone/Lucas four-point probe, numerous Nikon and Olympus microscopes, Nanometrics film measurement system, MRK Image Analysis and Dimensional Measurement System, CEE Photoresist coater, Blue M softbake and hardbake ovens, particle counter, Tencor Profilometer, Simitool Spin Rinser Dryers, Wentworth wafer prober, K&S wire bonder and David Mann photomask pattern generator and step & repeat cameras. The facility is plumbed with dry nitrogen from external liquid storage tanks and provided with a DI water system operating as a closed loop system to maintain better than 18 meg ohm water purity. The engineering facility also has available a Hitachi SEM with EDAX capability. Environmental control is monitored to assure maintenance of lab temperature, humidity and cleanliness.

Level of Cleanliness

The facility is designed to be a class 1000 clean-room. Instrumentation indicates that the facility exceeds this level of cleanliness. At all times, the facility is maintained at a temperature of 66-68 degreed F and the humidity is 40-42 percent. The entire room sits on an isolated slab with its own air conditioning and environmental control system. The facility is maintained under positive pressure and air is recirculated, traveling from ceiling to floor in a vertical flow pattern and returned through a closed plenum. Exhaust air is made up by outside conditioned filtered air.

Capabilities and Uses

The facility is used to support research, development and education across the University. The facility supports microelectronics instruction and research in the Electrical Engineering Department. Students are taught processing and clean room techniques, use of basic layout tools, verification of circuit design through observations and measurement of circuit parameters, lab safety, modeling and simulation. The lab is used to train technicians on clean room operations. Students in Technology are taught equipment operations, safety, calibration, chemicals used in microcircuits, and process technology. The lab is used for the development of new devices such as optical, chemical, thermal, pressure and acoustic wave sensors. Portions of the lab will be used to verify failure mechanisms. The lab will be used to support micromanufacturing. Processes including photolithography, diffusion, oxidation, chemical and physical vapor deposition, plasma etching and wet chemistry are included.

Summary Content in the Outer Cover Page

The fabrication Development Center, located on the Campus of Alabama A&M University in the School of Engineering, provides the personnel and resources to support research, development and education activities in the microlectronics, nanoelectronics and MEMs disciplines while also providing facilities for the design, development and analysis of prototype devices. The Center includes a 2500 sq. ft. clean room facility with state of the art environmental control systems and equipment.

The aforementioned text is provided in the FDC brochure as shown in **Figure 2**.

LABORATORY FACILITIES

The laboratory comprises of several instruments. Some of them are displayed in the photographs given in **Figures 3 through 9**. In these viewgraphs both clean room and the FACT Laboratory instruments are shown although several instruments are procured from other funding sources. Each of these instruments is identified and it is shown that the students are progressing with their ***laboratory practices*** (practicum courses) described with captions along with the presence of the students during the laboratory sessions.

LIST OF THE INSTRUMENTS PROCURED

The AFOSR fund **($180,000)** has been used to procure instruments for the FACT and FDC facilities in the Department of Electrical Engineering at AAMU. Some features of these instruments are described.

1. CHA 600 Dual E-Beam Evaporator

This e-beam evaporator allows metallization and/or electroding on to the semiconductor surfaces besides obtaining thin film structures on the substrates as high vacuum such as 10^{-6} *torr*.

2. Technics PE IIA Planar Plasma Etching System

This etching system allows etching semiconductor surfaces and primarily aimed to use for silicon surfaces.

3. Signitone/Lucas SYS-301-4 Four Point Probe

The four point probe will be used for measuring van der Pauw resistivity of semiconductors. This is useful for any geometry of the semiconductor sample.

4. NIKON Optiphot 66 Microscope

This microscope will be used making contacts and viewing semiconductor surfaces. It has 100 X capability.

5. HEM 2000/0.51T – SP Hall Effect Measurement System

The Hall Effect measuring system is conducive for obtaining carrier concentration in the semiconductors. The measurement can be conducted at 0.51 Tesla which is adequate for silicon.

6. HP4145B Semiconductor Parametric Analyzer

The semiconductor parameteric analyzer provides device-related parameters for junction devices. This unit is perfect for silicon based devices.

7. Solartron 1260 Impedance Analyzer

The Impedance Analyzer allows measurement in the range *10 mHz* through 32 *MHz*. It is an excellent characterization unit for junction semiconductors for detecting underlying operative mechanisms via equivalent circuit representation. Equivalent circuit can be developed through the complex plane formalisms of the impedance or admittance data.

8. Keithley 6517A Electrometer and High Resistance Meter

This electrometer is useful in measuring both voltage and current in a circuit. Thus, it will be used in measuring the current-voltage behavior of the semiconductor based junction devices.

9. Multi-Probe with Probe Head Accessories using MHP/MWP

This is a miniaturized probe for quick assessment of resistivity of a sample.

10. Instrument Controller Accessories and Laboratory Supplies

Instrument controller accessories are essential to run the instruments while acquiring data and conducting subsequent analysis. Instruments are interfaced for performing these tasks by the students.

The rest of the instruments listed in the brochures for the **FACT** and **FDC** facilities are procured by using other funds. Thus, **Figures 1 through 9** contain the aforementioned instruments beside other instruments that are funded by other projects.

CONCLUSIONS

The AFOSR fund was utilized efficiently where the Dollar amount was maximized procuring used and/or re-conditioned instruments. Also new instruments were procured as used items were not available at suitable pricing. Utilizing this fund the concept of **FACT** and **FDC** facilities were materialized. The Undergraduate students are receiving ***Laboratory Practices*** (**Practicum Courses**) for their two Microelectronics option courses.

KEY PERSONNEL

The activities of the key personnel are provided below. The PI, Dr. M. A. Alim, had been continuously engaged in procuring necessary instruments utilizing **AFOSR** fund. He has also used his research funds from NASA and MDA. Dr. K. B. Cook has supplied some of the photographs of the instruments along with the students in the laboratory facilities that are used in this Report.

1. Dr. M. A. Alim (P.I.)

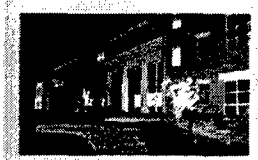
Dr. Alim is an *Associate Professor* in the Department of Electrical Engineering at Alabama A & M University (AAMU) and also the contact person for the **FACT** (Failure Analysis, Characterization, and Testing) **Laboratory** facility. He has been awarded **Researcher of the Year 2003** at AAMU on August 14, 2003. He possesses cumulative 12+ years industrial and consulting experience prior to joining AAMU in August 1998. Besides this he also possesses 8+ years teaching experience. His diverse research expertise involves variety polycrystalline semiconductors for both electrical component and integrated/discrete electronic device applications. He has some 88+ publications in the international journals and conference proceedings beside co-editing 2 books, obtaining 5 U.S. patents, and 6 book chapters. He has visited Canada, China, India, Ireland, and Bangladesh upon invitation to present seminar talks and offer short courses beside the institutions within the U.S.A.

2. Dr. K. B. Cook (Co-I)

Dr. Cook was in this project as a co-Investigator. He is the contact person for the Fabrication Development Center (**FDC**) comprising primarily of the clean room arena with the assistance of Dr. Zhigang Xiao.

Failure Analysis, Characterization and Testing Laboratory

This facility provides the personnel and resources to support research activities in the Microelectronics option emphasizing Bulk Nano-Electronics while serving conventional and innovative smart novel Hybrid Devices.



Engineering and Technology Building

FACT Laboratory

Department of Electrical Engineering

School of Engineering and Technology
133 Chase Road
Normal, AL 35762

Contacts

Dr. Mohammad Alim
mohammad.alim@email.aamu.edu
(256) 372-5562

Mr. Dave Pett
david.pett@aamu.edu
(256) 372-5023

Dr. Trent Montgomery
trent.montgomery@email.aamu.edu
Phone: 256-372-5590
Fax: 256-372-5855

Research, Development and Education

Failure Analysis, Characterization and Testing (FACT) Laboratory

Alabama A&M University

Normal, AL 35762

Department of Electrical Engineering

256-372-5590

Failure Analysis, Characterization and Testing (FACT)

The Failure Analysis, Characterization, and Testing Facilities have the capabilities to support evaluation of the Microelectronic Systems based on both Single Crystals and Polycrystals technologies using state-of-the-art instrumentation. The Microelectronic Systems include both Unipolar and Bipolar Junction Devices and often noted as Hybrid Device Systems for the Polycrystalline Semiconductors. This facility supports the Microelectronics option program offered by the Department of Electrical Engineering. This program option offers four specialty courses dedicated to the area of Microelectronics having about a dozen of students per year. Students finishing this program are exposed to the projects involving device electronics and integrated circuits including modeling of conduction processes and equivalent circuit modeling. Also they are exposed to the studies on the degradation and bias stability of the Hybrid Systems.

University and government representatives discuss testing problems

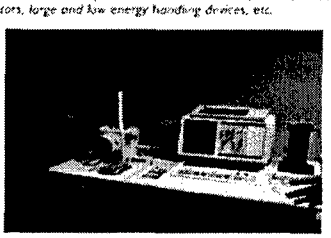
Work in this facility is under the direction of Dr. M. A. Alim, Associate Professor in the Department of Electrical Engineering. He has initiated developing this facility in conjunction with the development of the Fabrication Development Center within the Department of Electrical Engineering. He has directed and guided numerous product related projects in a diversified arena extensively teaching a variety of Hybrid Microelectronic Devices and Systems using large and small band gap electronic materials in Private Industries, Government Organizations, and Academic Institutions in Alabama, Tennessee, Ohio, and Wisconsin. Dr. Alim has taught and developed each of the Microelectronic option courses and collaborated with the University of Massachusette at Lowell to develop an active Microelectronics option program at Alabama A & M University. His involvement includes research activities on electrical components such as resistors, capacitors, inductors, transformers, resonators, varistors, thermistors, sensors, etc.

Instrumentation and Tools

The Impedance Spectroscopy (Impedance or Admittance) is a powerful non-destructive tool in delineating underlying competing operative phenomena in variety materials and devices. Thus, it provides characterization as well as evaluation and quality control of the end products via smart technique. For characterization and evaluation purposes ultimately an equivalent circuit model can be developed. The Department of Electrical Engineering is equipped with two impedance analyzers (HP4192A and Solartron 1260) ranging measurement frequencies from 1 mHz through 13 MHz. Semiconductors are analyzed via four-point probing as well as Hall Effect – van der Pauw techniques. Single junction devices can be analyzed using HP4145 Semiconductor Parametric Analyzer. Junction features of variety semiconductor devices are evaluated with the Scanning Electron Microscopy (SEM) Facility. The elemental analyses of selected areas of the devices or junctions are also possible using EDS (Energy Dispersive Spectroscopy) technique.

Anticipated Uses

Although the **Failure Analysis, Characterization, and Testing (FACT) Facilities** *is developed for Microelectronics students to support the curricula and conducting research in the Department of Electrical Engineering but it is accessible and available to support other organizations according to their requirements. This facility is also available to conduct basic and applied research to achieve an eventual product. It is a perfect facility to initiate SBIR (Small Business Innovation Research) in addition to large organizations' base needs. All tools/techniques noted herein are available for innovating solid-state (semiconductor) based devices for variety sensors, transducers, thermisters, thyristors, electrical components (resistors, capacitors, inductors, transformers, etc.), varistors, large and low energy handling devices, etc.*



Scanning Electron Microscope is used for analysis of materials

Other tools and techniques are readily available for use. Among those are highlighted as various Crystal Growth Techniques, Bulk, Nano Powders, X-Ray Diffraction (XRD), Elemental Analysis via ICP-AES, etc. Degradation studies of materials and devices can be conducted using all the tools and techniques noted above, and then solutions may be provided to the problems of the end products.

The FACT center will also support research in material characterization, device design and development, performance demonstration under non-nominal conditions and device manufacture. The center will be an industry recognized resource for component and device testing. The center will bring together the technical talent of subject matter experts in academia, Government and industry with the resources of the FACT laboratory to do microelectronics component and device testing. The laboratory will be equipped to do Burn-in and Qualification testing, Stress, Accelerated Stress and Accelerated Lifetime Testing, small batch Environmental Stress Testing and Failure Analysis of microelectronics components and devices. The FACT laboratory will be used to train students in the processes and techniques of microelectronic device testing and analysis. Students will be exposed to the performance realities of "real" devices under stress, and will be trained to analyze the cause of failures in the devices they design. Students will be instructed in the requirements, procedures and techniques of qualification, stress and accelerated lifetime testing. They will learn the basic process of failure analysis. They will leave the program with an understanding of the design and build process and will have developed the familiarity with real devices that can only be gained from performance testing and analysis of failures.

Department of Electrical Engineering

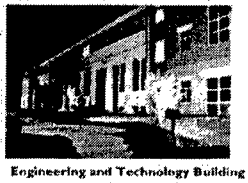
School of Engineering and Technology
133 Chase Road
Normal, AL 35762

Dr. Trent Montgomery
trent.montgomery@email.aamu.edu
Phone: 256-372-5590

Figure 1. Failure Analysis, Characterization, and Testing (**FACT**) Laboratory brochure (outer and inner pages). The clear text is reproduced in the **FEATURES OF THE LABORATORY FACILITIES** (section 1).

Fabrication Development Center

The Fabrication Development Center, located on the Campus of Alabama A&M University in the School of Engineering, provides the personnel and resources to support research, development and education activities in the microelectronics, nanoelectronics and MEMs disciplines while also providing facilities for the design, development and analysis of prototype devices. The Center includes a 2500 sq. ft. clean room facility with state of the art environmental control systems and equipment.



Engineering and Technology Building

Department of Electrical Engineering

School of Engineering & Technology
133 Chase Road
Normal, AL 35762

Contacts

Dr. Koy Cook
koy.cook@email.aamu.edu
(256) 372-5561

Dr. Zhigang Xiao
xiao@eim.aamu.edu
(256) 372-5894

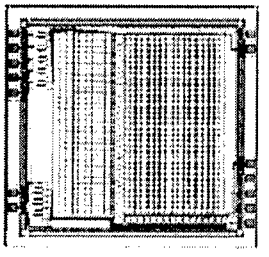
Dr. Trent Montgomery
trent.montgomery@email.aamu.edu
Phone: 256-372-5590
Fax: 256-372-5855

Research, Development And Education

Fabrication Development Center

Alabama A&M University

Normal, AL 35762



Department of Electrical Engineering

Fabrication Development Center

The Fabrication Development Center includes a team of instructors and advanced students providing the capability to develop prototypes, support research and education in microelectronics. The development team makes use of a 2500 square foot clean room to fabricate solid state devices or complete IC chips. The facility also supports the Department of Electrical Engineering's microelectronics concentration. This program option offers specialty courses dedicated to the area of solid state electronics. Students in the program have designed projects such as digital memory systems and linear operational amplifiers.

Microelectronics Students Process Silicon Wafers

Work in the facility is carried out under the direction of Dr. Koy B. Cook and Dr. Zhigang Xiao, professors of electrical engineering. Dr. Cook has 30 years of combined experience directing projects in industry and teaching engineering at universities in Alabama and Florida. Here at Alabama A&M, Dr. Cook's students use Multisim and Tanner TCAD tools to design and simulate IC chips. Most recently, students are using Silvaco Supreme Process Simulation tools to develop advanced processes for silicon structures. Dr. Xiao has taught electrical engineering for over ten years. Both Professors have experience in process engineering including plasma-enhanced chemical vapor deposition, low pressure chemical vapor deposition, thin films, photolithography, diffusion, and ion implantation. Dr. Xiao's most recent work has been in nanotechnology and Dr. Cook's in sensors. Dr. Cook is a senior member of the IEEE and a registered professional engineer. Both have extensive publications.

Equipment

The Fabrication Development Center contains the basic process and fabrication tools necessary to develop new technology or instruct in microelectronics. Fabrication equipment includes a state-of-the-art custom computer controlled six-tube Steed diffusion furnace system with expansion capability for LPCVD polysilicon and silicon nitride, custom CHA dual e-beam evaporator, Karl Suss MA 56 mask aligner, Tempress dicing saw, Westbond die bonder, , Rudolph ellipsometer, Technics planar plasma etch system, Technics etcher/stripper, numerous class-100 laminar flow dry and wet work stations, Signatone/Lucas four-point probe, numerous Nikon and Olympus microscopes, Nanometrics film measurement system, MRK Image Analysis and Dimensional Measurement System, CEE Photoresist coater, Blue M softbake and hardbake ovens, particle counter, Tencor Profilometer, Similtool Spin Rinser Dryers, Wentworth wafer prober, K&S wire bonder and David Mann photomask pattern generator and step & repeat cameras. The facility is plumbed with dry nitrogen from external liquid storage tanks and provided with a DI water system operating as a closed loop system to maintain better than 10 meg ohm water purity. The engineering facility also has available a Hitachi SEM with EDAX capability. Environmental control is monitored to assure maintenance of lab temperature, humidity and cleanliness.

All devices are given a thorough inspection

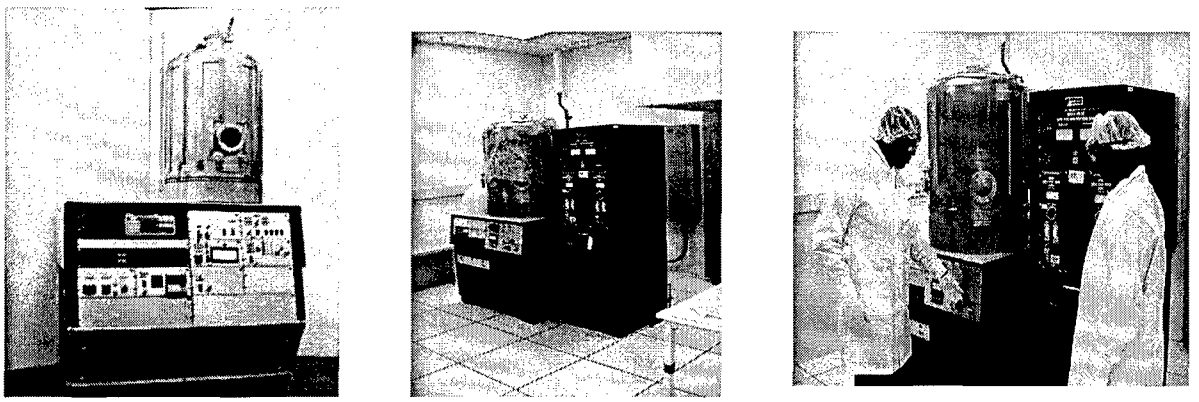
Level of Cleanliness

The facility is designed to be a class 10000 cleanroom. Instrumentation indicates that the facility exceeds this level of cleanliness. At all times, the facility is maintained at a temperature of 66-68 degrees F and the humidity is 40-42 percent. The entire room sits on an isolated slab with its own air conditioning and environmental control system. The facility is maintained under positive pressure and air is recirculated, travelling from ceiling to floor in a vertical flow pattern and returned through a closed plenum. Exhaust air is made up by outside conditioned filtered air.

Capabilities and Uses

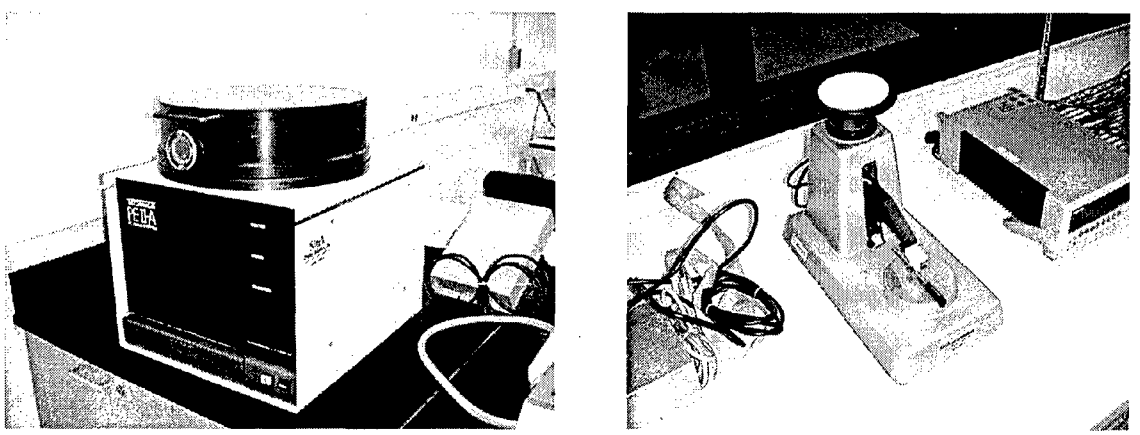
The facility is used to support research, development and education across the University. The facility supports microelectronics instruction and research in the Electrical Engineering Department. Students are taught processing and clean room techniques, use of basic layout tools, verification of circuit design through observations and measurement of circuit parameters, lab safety, modeling and simulation. The lab is used to train technicians on clean room operations. Students in Technology are taught equipment operations, safety, calibration, chemicals used in microcircuits, and process technology. The lab is used for the development of new devices such as optical, chemical, thermal, pressure and acoustic wave sensors. Portions of the lab will be used to verify failure mechanisms. The lab will be used to support micromanufacturing. Processes including photolithography, diffusion, oxidation, chemical and physical vapor deposition, plasma etching and wet chemistry are included.

Figure 2. Fabrication Development Center (**FDC**) brochure (outer and inner pages). The clear text is reproduced in the **FEATURES OF THE LABORATORY FACILITIES** (section 2).



(*a*) (*b*) (*c*)

Figure 3. CHA 600 Dual E-Beam Evaporator (*a*) as-received; (*b*) in the clean room; and (*c*) with the students in the clean room.



(*a*) (*b*)

Figure 4. Two instruments in the clean room: (*a*) Technics PE IIA Planar Plasma Etching System; and (*b*) Signitone/Lucas SYS-301-4 Four Point Probe measuring set up.

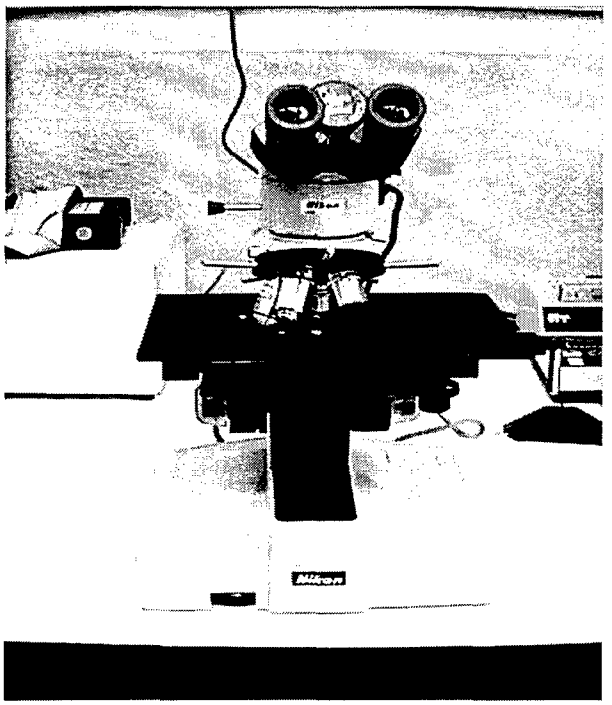
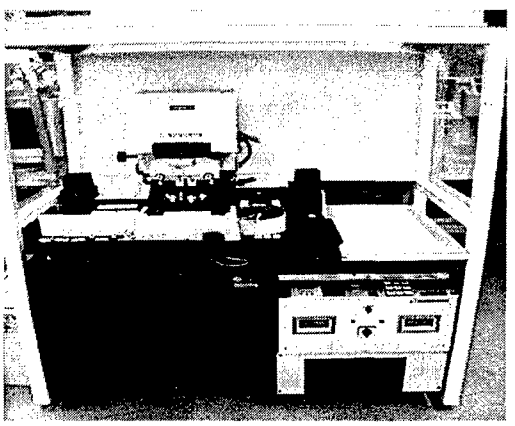
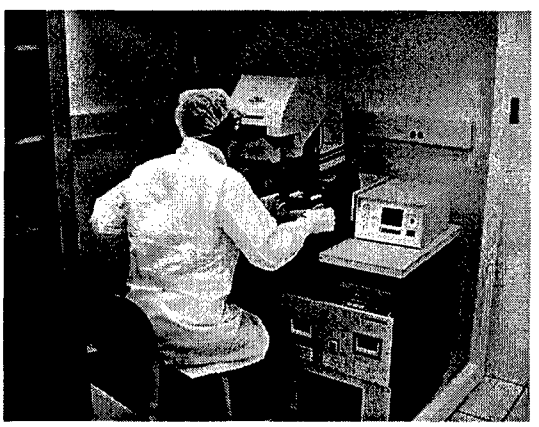


Figure 5. The NIKON Optiphot 66 Microscope in the clean room.

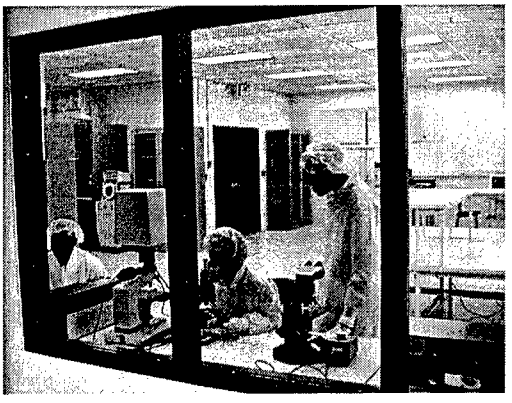


(*a*)

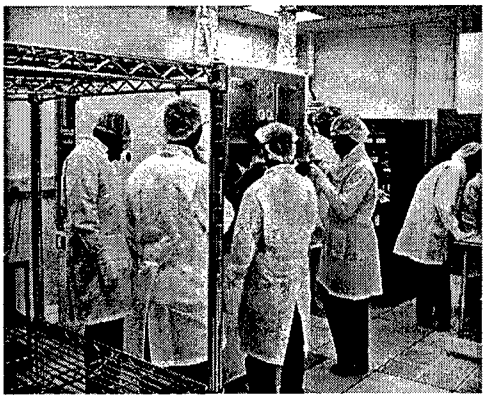


(*b*)

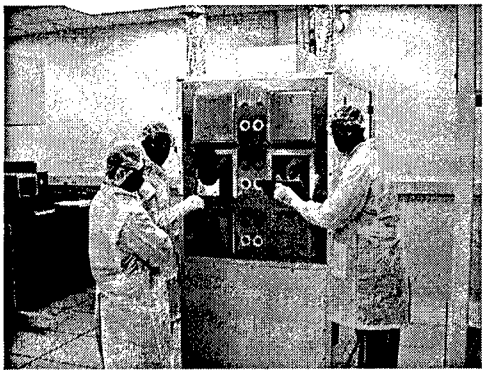
Figure 6. (*a*) The Karl Zuss MA 56 Mask Aligner in the clean room; and (*b*) Student performing mask alignment.



(*a*)



(*b*)



(*c*)

(*d*)

(*e*)

Figure 7. Clean room activities: (*a*) Students with several microscopes viewed from outside the clean room; (*b*) Students working in the clean room; (*c*) Students working with the horizontal diffusion furnace; (*d*) Students working with measurement tools in the clean room; and (*e*) Students progressing work in process using various instruments.

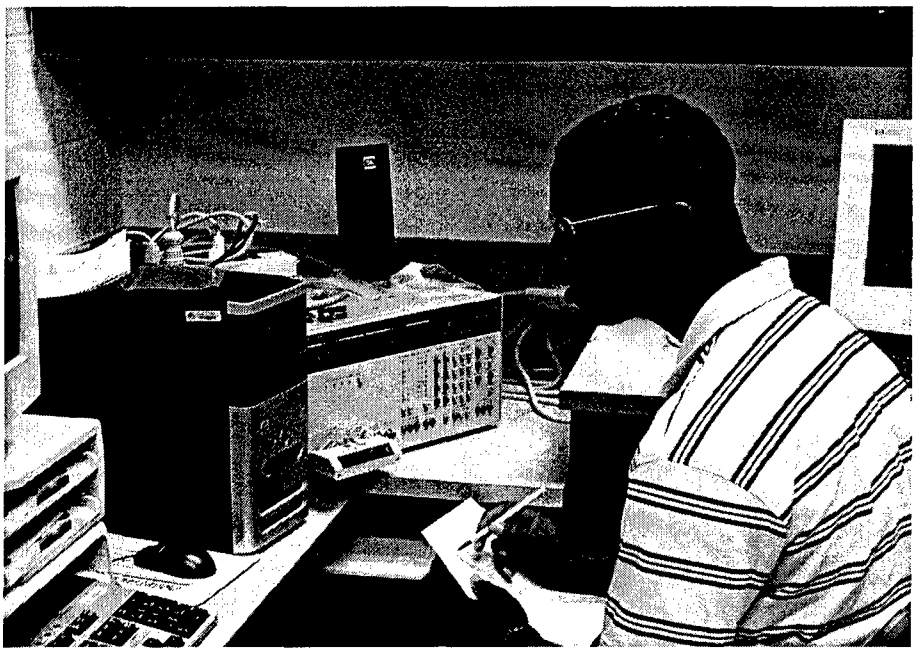


Figure 8. Student working on semiconductor device characterization using impedance analyzer in the **FACT** Laboratory.

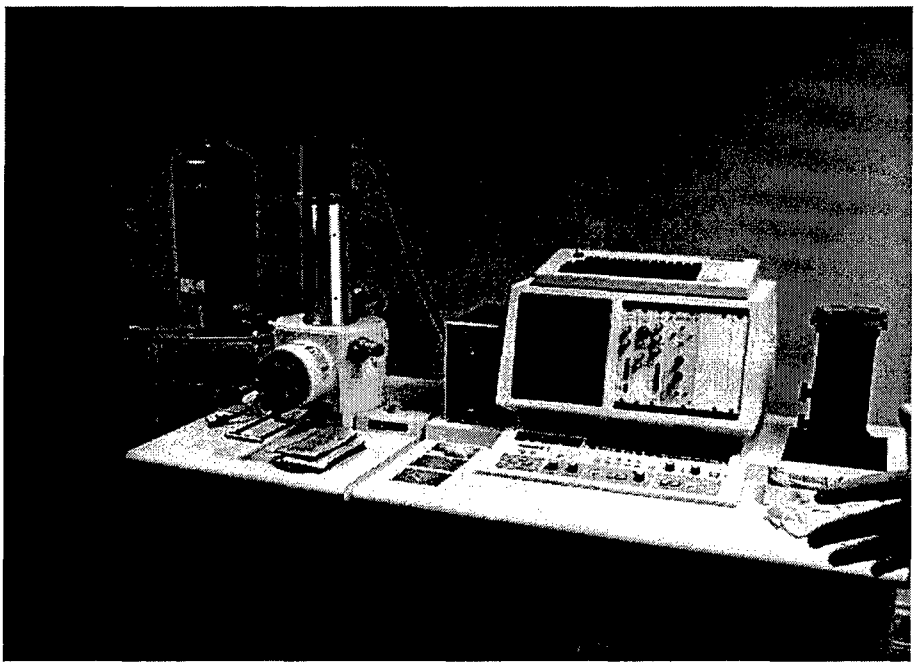


Figure 9. Scanning Electron Microscope (SEM) used for the analysis of variety materials in the **FACT** Laboratory. [Received as donation from a local company in Huntsville, Alabama.]

REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-05-

0329

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
30-06-2005	Final (Previously Sent Final Report is Missing)	September 15, 2002 - September 14, 2003

4. TITLE AND SUBTITLE

Processing and Testing Instrumentation for the Microelectronics Laboratory

5a. CONTRACT NUMBER

Award # F-49620-02-1-0441

5b. GRANT NUMBER

AFOSR/PK2 code FA9550

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Dr. M. A. Alim (Principal Investigator)

[Additional Personnel Listed in this Project is Dr. K. B. Cook as the Co-Investigator.]

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Alabama A & M University, P.O. Box 297, Normal, Alabama 35762

8. PERFORMING ORGANIZATION REPORT NUMBER

Dr. M. A. Alim / June-30-2005

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Office of Scientific Research (AFOSR)
4015 Wilson Boulevard, Arlington, Virginia 22203 - 1954

10. SPONSOR/MONITOR'S ACRONYM(S)

AFOSR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

Control No. ISP02-I65

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution unlimited.

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

13. SUPPLEMENTARY NOTES

This report is prepared by the PI.

14. ABSTRACT

The Microelectronics Laboratory in the Department of Electrical Engineering at Alabama A & M University (AAMU) has acquired basic infrastructure instruments for both processing and characterization purposes. These instruments accommodate necessary vital components of running an initial stage laboratory experiments for the Undergraduate courses for the students in the Microelectronics option. Though this laboratory is not complete but serves the initial purpose at this moment for these Undergraduate students. Some characterization instruments may be used for testing and evaluation as well. Several sources of funds including this AFOSR fund are used in erecting this laboratory at the functional level. Further funding sources are continuously sought from several corners to run this laboratory. The list of the instruments along with the installed photographs is provided in this Report.

15. SUBJECT TERMS

Microelectronics, Laboratory, Pressing, Characterization, Testing, Evaluation, etc.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Dr. M. A. Alim
U	U	U	SAR	19	19b. TELEPHONE NUMBER *(Include area code)* (256)-372-5562

8-4-05